

*WITHIN-SUBJECT TESTING OF THE SIGNED-REINFORCEMENT EFFECT ON
OPERANT RESPONDING AS MEASURED BY RESPONSE RATE AND
RESISTANCE TO CHANGE*

PHIL REED AND ADAM H. DOUGHTY

UNIVERSITY OF WALES SWANSEA AND WEST VIRGINIA UNIVERSITY

Response rates under random-interval schedules are lower when a brief (500 ms) signal accompanies reinforcement than when there is no signal. The present study examined this signaled-reinforcement effect and its relation to resistance to change. In Experiment 1, rats responded on a multiple random-interval 60-s random-interval 60-s schedule, with signaled reinforcement in only one component. Response resistance to alternative reinforcement, prefeeding, and extinction was compared between these components. Lower response rates, and greater resistance to change, occurred in the component with the reinforcement signal. In Experiment 2, response rates and resistance to change were compared after training on a multiple random-interval 60-s random-interval 60-s schedule in which reinforcer delivery was unsignaled in one component and a response-produced uncorrelated stimulus was presented in the other component. Higher response rates and greater resistance to change occurred with the uncorrelated stimulus. These results highlight the significance of considering the effects of an uncorrelated signal when used as a control condition, and challenge accounts of resistance to change that depend solely on reinforcer rate.

Key words: signaled reinforcement, response strength, resistance to change, learning, lever press, rat

A brief stimulus presented along with reinforcement on a random-interval (RI) schedule of reinforcement serves to decrease rates of responding (Pearce & Hall, 1978; Reed, Schachtman, & Hall, 1988; St. Claire-Smith, 1979). One interpretation of this effect is that the reinforcement signal serves as a better predictor of reinforcement than the response. The stimulus is perfectly correlated with the delivery of reinforcement, whereas the response sometimes occurs in the absence of the reinforcer. Consequently, some investigators have argued that the stimulus gains associative strength at the expense of the response, and that the strong stimulus-reinforcer association overshadows the weaker response-reinforcer association. According to this line of theorizing, overshadowing would lead to a lower response rate in the signaled-reinforcement condition compared to the unsignaled condition (see Pearce & Hall, 1978; St. Claire-Smith, 1979).

Another interpretation of the signaled-reinforcement effect is that a signal presented prior to reinforcement actually increases the salience of the molar characteristics of the RI schedule (Roberts, Tarpy, & Lea, 1984). According to this view, the signal-induced attenuation of responding on an RI schedule reflects enhanced learning that responding above a certain minimum rate on an RI schedule will not increase reinforcer rate. Lower rates of responding on RI schedules reflect more efficient responding in terms of the number of responses emitted per reinforcer. This response-efficiency view predicts a different effect of signaling reinforcement on schedules in which reinforcer delivery is contingent upon higher rates of responding, such as variable-ratio (VR) or differential-reinforcement-of-high-rate (DRH) schedules. According to the response-efficiency account, a brief signal for reinforcement on these latter two schedules should increase response rate because this increase would produce more reinforcers per unit time than lower response rates. This predicted signal-induced potentiation of responding on VR and DRH schedules has been observed (e.g., Reed, 1989; Reed et al., 1988; Tarpy & Roberts, 1985). The overshadowing interpretation (Pearce & Hall, 1978) of the signaled-reinforcement effect cannot account for such a response-rate increase on VR and DRH sched-

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Requests for reprints can be sent to either: Phil Reed, Department of Psychology, University of Wales Swansea, Singleton Park, Swansea, SA2 8PP, United Kingdom (e-mail: p.reed@swansea.ac.uk), or Adam H. Doughty, University of Kansas, Schiefelbusch Institute for Life Span Studies, Parsons Research Center, PO Box 738, 2601 Gabriel, Parsons, Kansas 67357 (e-mail: adoughty@ku.edu).

ules because a stimulus that always is paired with reinforcer delivery, and is a better predictor of reinforcement than the response, always ought to reduce response rates.

In describing the effects of a brief signal on learning, most researchers have inferred the strength of learning from response rate. Of course, there are other means to test strength of learning, including resistance-to-change tests. Roberts et al. (1984) investigated the signaled-reinforcement effect in a study that included resistance-to-change measures. For one group of rats, a signal was presented immediately prior to reinforcement on an RI schedule; the signal was omitted for another group. As in the studies noted above, the signaled-reinforcement group responded at a lower rate than the unsignaled-reinforcement group. Roberts et al. also obtained greater signal-induced resistance to prefeeding (i.e., satiation) and extinction, despite the lower response rates in the baseline-training phase. This dissociation between response rate and resistance to change is difficult for the overshadowing view of signaled reinforcement to accommodate, and shows that response rate and resistance-to-change measures can lead to different interpretations of response strength.

The purpose of the present experiments was to examine the generality of the findings reported by Roberts et al. (1984). In particular, the present study employed a within-subject rather than between-subject design and included alternative reinforcement as a disrupting operation (e.g., Nevin, Grace, Holland, & McLean, 2001), in addition to the extinction and prefeeding procedures used by Roberts et al. Thus the general aim of the present study was to evaluate the effects of signaled reinforcement on response strength, as measured by response rate and resistance to change.

EXPERIMENT 1

Experiment 1 evaluated response rates and resistance to change in rats under a multiple RI RI schedule. In one component, a 500-ms tone was presented along with reinforcement, and in the other component this stimulus was omitted. Following this initial phase, response resistance to alternative reinforcement, prefeeding, and extinction was compared be-

tween the two components. If lower response rates occurred in the component with signaled reinforcement during initial training, then the generality of the signaled-reinforcement effect would be demonstrated within individual subjects. If greater resistance were obtained during the component with signaled reinforcement, then further support would be obtained for the claim that a signal for reinforcement enhances learning, or response strength. This set of findings also would demonstrate that the two measures, response rate and resistance to change, do not always produce the same direction of results.

METHOD

Subjects

Four male Lister hooded rats, naive to the conditions of the experiment, were employed. The rats previously were trained to lever press and retrieve food from the magazine. They were approximately 7 to 8 months old at the start of training and had a free-feeding body weight range of 385 to 415 g. The rats were housed together and fed to maintain their 85% free-feeding body weights. Constant access to water in the home cage was provided.

Apparatus

Four identical operant conditioning chambers were used. Each chamber was located in a sound- and light-attenuating box equipped with a ventilation fan that provided a background masking noise of 65 dB(A). Each chamber measured 235 mm wide by 235 mm long by 205 mm high. On one wall of the chamber were two identical response levers located 30 mm to each side of a centrally located food tray and 30 mm from the floor. The food tray was covered by a hinged, clear Perspex flap, behind which reinforcement (one 45-mg Noyes food pellet) was delivered. A jeweled light was positioned 30 mm above each lever. A speaker mounted on the ceiling of the chamber delivered a 105 dB(A) tone (40 dB above background). The tone was a broad-band, noisy signal (ranging up to 16 kHz) with spectral peaks at 3 kHz and 500 kHz.

Procedure

Pretraining. The rats received six, 40-min pretraining sessions in which responding was

maintained under a concurrent RI 30-s RI 30-s schedule to generate equal rates of responding to each lever.

Phase 1: Baseline training. The rats then were exposed to a multiple RI 60-s RI 60-s schedule. The RI schedule was generated by a BBC Series B computer that assigned a probability of reinforcement of 1/60 every second. During one of the components, the light above the left (for 2 rats) or right (for the other 2 rats) lever was illuminated for 3 min, and only responses to that lever resulted in food delivery. Food delivery in this component was accompanied by a 500-ms tone. At the end of this 3-min component, a 30-s intercomponent interval (ICI) occurred during which all lights were extinguished and no responses were reinforced. Following the ICI, the next component began. During the second component, the light above the other lever was illuminated for 3 min and only responses to that lever were reinforced. No tone accompanied reinforcer delivery. After this component terminated, another ICI followed, and then the cycle started again. The cycle repeated eight times per session. This phase lasted 10 sessions.

Phase 2: Resistance to variable-time schedule food during the ICI. Phase 2 was similar to Phase 1, except that food was delivered during the ICI according to a variable-time (VT) 30-s schedule (i.e., response-independent food delivery). This phase continued for 10 sessions.

Phase 3: Baseline training. The rats were returned to the initial training condition, described in Phase 1, for 12 sessions.

Phase 4: Resistance to prefeeding. Immediately following Phase 3, the rats were fed their daily allotment of food 2 hr prior to the next session. The rats then were given two further sessions of multiple RI 60-s RI 60-s baseline training, followed by another prefeeding session.

Phase 5: Resistance to extinction. All rats then were given two further sessions of multiple RI 60-s RI 60-s baseline training, followed by three extinction sessions. These extinction sessions were similar to baseline training, except that no food or tones were presented.

RESULTS AND DISCUSSION

The rates of responding over Phases 1 (baseline), 2 (ICI food), and 3 (baseline) for

each rat are displayed in Figure 1. Across the last four sessions of each phase, which were used for analysis, the response rates for all rats were reasonably stable and did not vary by more than five responses per minute over these sessions for any rat. In all phases, a greater number of responses typically occurred in the unsignaled component than in the signaled component for all rats. Response rates to the nonoperative lever were not substantial for any rat in any of the phases. During the last four sessions of Phase 2, response rates in each component were lower than they were in Phases 1 and 3, and the response rates were more similar to one another than they were in Phases 1 and 3. This latter effect was a result of the more marked response-rate decrease in the component with unsignaled reinforcement relative to the component with signaled reinforcement.

Figure 2 displays the average response rates from the last four sessions of Phase 2 (ICI food) calculated as a percentage of the rates from the last four sessions of Phases 1 and 3. For both baselines, this percentage of baseline responding was higher for all rats in the component with signaled reinforcement than in the component with unsignaled reinforcement.

Figure 3 displays the rate of responding during the two prefeeding sessions presented as a percentage of the immediately preceding baseline phase (i.e., the two sessions prior to the first prefeeding session and the two sessions prior to the second prefeeding session). Except for the first prefeeding for Rat 72, responding was reduced more in the component with unsignaled reinforcement than in the component with signaled reinforcement. Figure 3 also displays the rate of responding during the three sessions of extinction as a percentage of response rates in the two baseline sessions preceding extinction. For all rats, responding extinguished more slowly in the component that previously had signaled reinforcement than in the component that previously had unsignaled reinforcement. This effect occurred even though the change in stimulus contingencies from training to extinction was greater in the component with signaled reinforcement than in the component with unsignaled reinforcement, because the food and tone were removed in the former component, whereas only food was re-

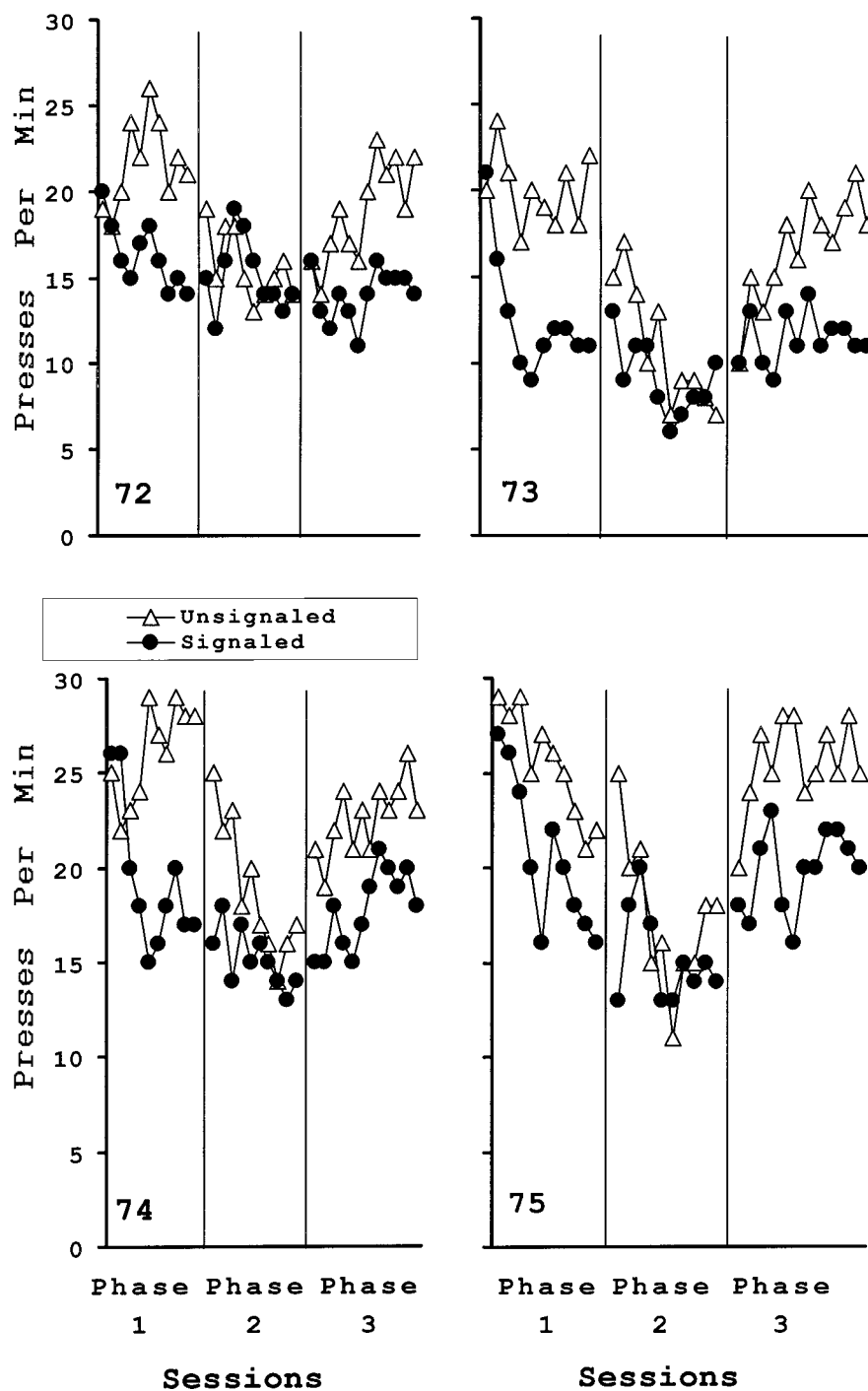


Fig. 1. Response rates for all rats in each component during all sessions of Phase 1 (baseline), Phase 2 (ICI food), and Phase 3 (baseline) in Experiment 1.

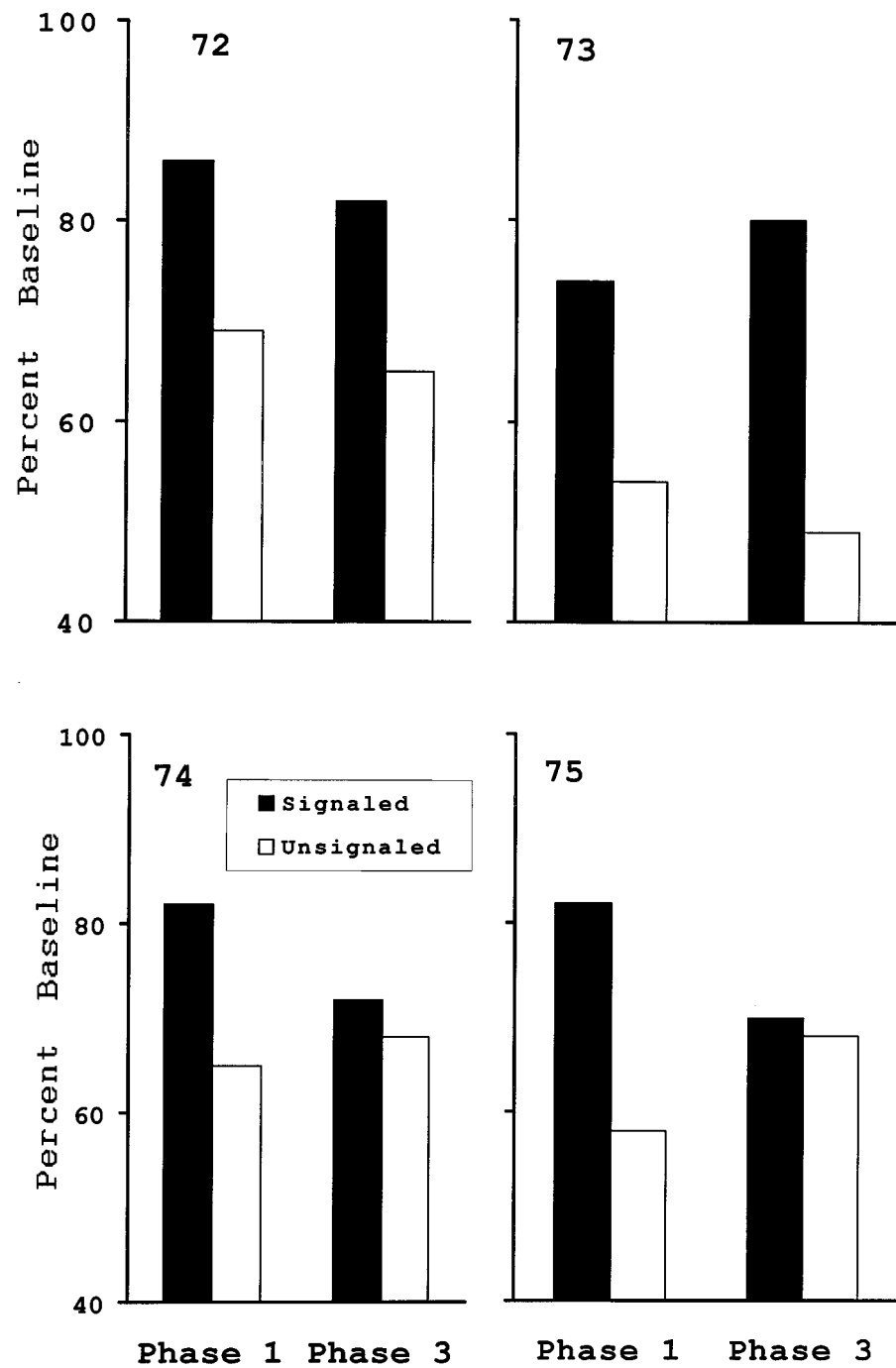


Fig. 2. Response rates for all rats in each component in Phase 2 (ICI food) expressed as a percentage of response rates from Phases 1 and 3 in Experiment 1.

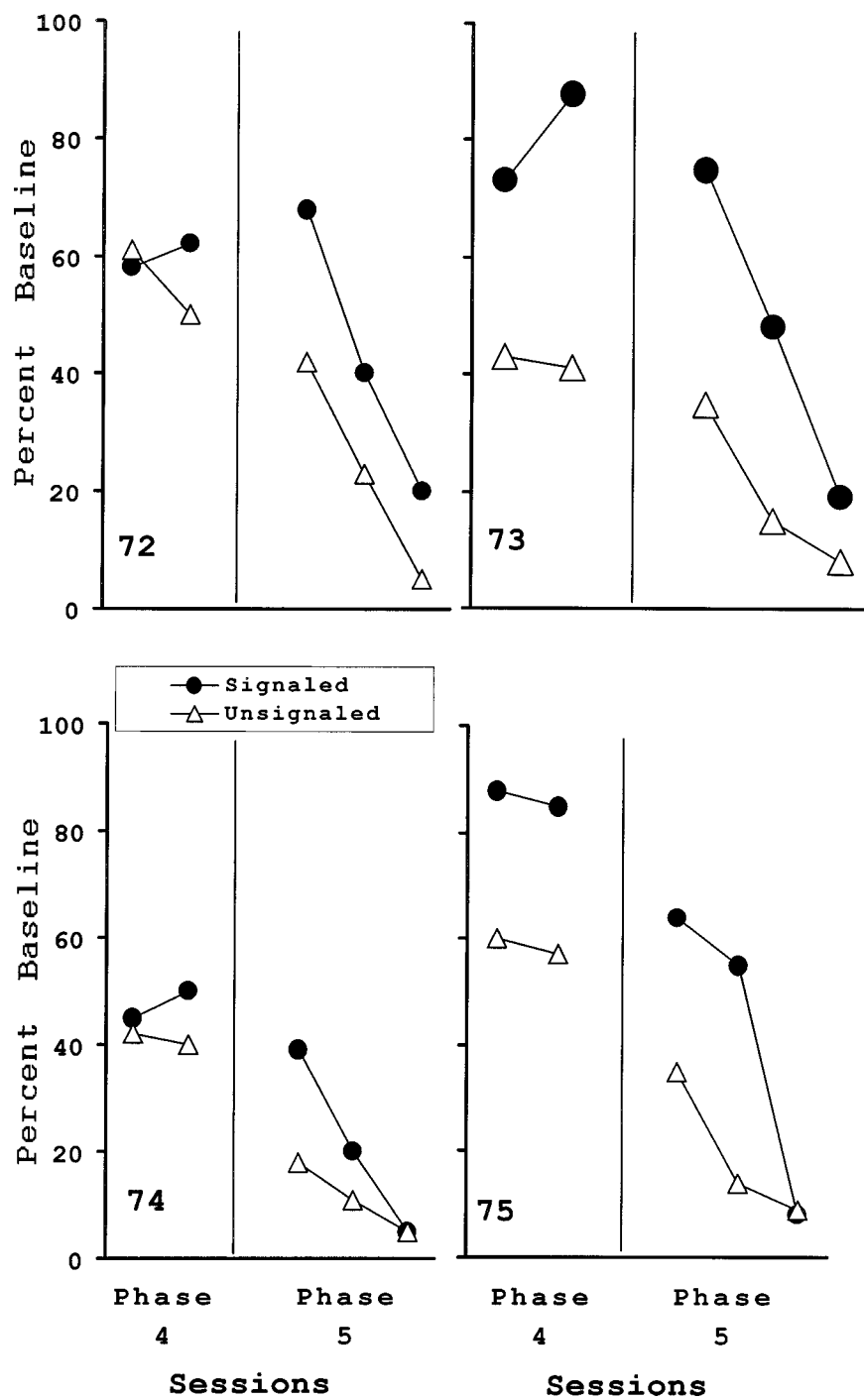


Fig. 3. Response rates expressed as a percentage of baseline for all rats in each component in Phase 4 (prefeeding) and Phase 5 (extinction) in Experiment 1.

moved in the component with unsignaled reinforcement. The data on which Figure 3 is based are displayed in Appendix A.

The present data replicate previous demonstrations of the signaled-reinforcement effect in studies employing between-group comparisons (e.g., Roberts et al., 1984) but using a potentially more sensitive within-subject design. That is, signal-induced attenuation of responding on an RI schedule was obtained under a multiple schedule in rats, a finding so far only noted in pigeons (see Schachtman, Reed, & Hall, 1987). Moreover, responding was more resistant to change, whether that change was alternative reinforcement, prefeeding, or extinction, when maintained by signaled reinforcement than unsignaled reinforcement. This latter finding is consistent with the suggestion that signaled reinforcement produces stronger learning than unsignaled reinforcement (Reed, 1989; Roberts et al., 1984).

EXPERIMENT 2

Experiment 1 demonstrated the signaled-reinforcement effect using a within-subject comparison in which reinforcer delivery was either signaled or unsignaled across components. The signaled-reinforcement effect also has been shown across groups in procedures in which a signaled-reinforcement condition is compared to a condition providing a response-dependent stimulus that is uncorrelated with reinforcement (e.g., Pearce & Hall, 1978; Roberts et al., 1984). The rationale for this latter comparison is to control for the effects on responding of the presentation of the stimulus per se. However, it has been demonstrated that response-dependent, reinforcement-uncorrelated stimuli are not neutral in their effects on behavior. That is, uncorrelated brief stimuli may serve to generate a "quasi-reinforcement" effect (e.g., Neuringer & Chung, 1967; Reed & Hall, 1989). A quasi-reinforcement effect is said to occur when the presentation of a putatively neutral stimulus acts on behavior in the same manner as a stimulus such as food for a hungry animal. However, the neutral stimulus does not necessarily possess conditioned reinforcing properties. In fact, the stimulus may actually pass tests for inhibition (see Reed & Hall, 1989). If such a stimulus is presented in

the manner outlined above, it may act to produce behavior consistent with a schedule on which the reinforcement rate was twice as high. For example, if reinforcers and stimuli were presented, each on an independent RI 120-s schedule, then the resulting behavior might be similar to that seen on an RI 60-s schedule, consequently leading to higher response rates than would otherwise occur.

Moreover, such a quasi-reinforcement effect also might result in greater resistance to change relative to an unsignaled condition. If such signal-induced differential resistance were to occur, then the results of Roberts et al. (1984) regarding the effect of a signal for reinforcement on resistance to change would be compromised. The latter experiment found greater resistance to change after training with signaled reinforcement compared to that seen after training with a stimulus presented uncorrelated with reinforcement. If the uncorrelated stimulus acted as a quasi-reinforcer, then a schedule with signaled reinforcement was being compared with a schedule combining unsignaled reinforcement and quasi-reinforcement. Thus it appears important to determine whether this uncorrelated stimulus presentation generated the resistance-to-change results by itself. In Experiment 2, therefore, we compared resistance to change of responding maintained by unsignaled reinforcement (i.e., in one multiple-schedule component) with responding in a second multiple-schedule component that had signals presented uncorrelated with reinforcement.

METHOD

Subjects and Apparatus

Four male Lister hooded rats, naive to the conditions of the experiment, were employed. The rats previously had been trained to lever press and retrieve food from the magazine. They were approximately 7 to 8 months old at the start of training, and had a free-feeding body weight range of 360 to 400 g. The rats were housed and maintained as described in Experiment 1. The apparatus was that described in Experiment 1.

Procedure

Pretraining. The rats received six 40-min pretraining sessions in which responding was

maintained under a concurrent RI 30-s RI 30-s schedule to generate equal rates of responding to each lever.

Phase 1: Baseline training. The rats then were exposed to a multiple RI 60-s RI 60-s schedule. During one of the components, the light above the left (for 2 rats) or right (for the other 2 rats) lever was illuminated for 3 min, and only responses to that lever resulted in food delivery. No tone was presented during this component. At the end of this 3-min component, a 30-s ICI followed in which all lights were extinguished and no responses were reinforced. Following the ICI, the next component began. During this component, the light above the other lever was illuminated for 3 min and only responses to this lever were reinforced. A 500-ms response-dependent tone was presented on an independent RI 60-s schedule during this component. After this component terminated, the ICI followed, and then the cycle started again. The cycle repeated eight times per session. This phase lasted 10 sessions.

Phase 2: Resistance to VT food during the ICI. Phase 2 was similar to Phase 1 except that food was delivered during the ICI according to a VT 30-s schedule (i.e., response-independent food delivery). This phase continued for 10 sessions.

Phase 3: Baseline training. The rats were returned to the initial training condition, described in Phase 1, for 10 sessions.

Phase 4: Resistance to prefeeding. Following Phase 3, for one session, the rats were fed their daily allotment of food 2 hr prior to the session. The rats then were given two further sessions of multiple RI 60-s RI 60-s baseline training followed by another prefeeding session.

Phase 5: Resistance to extinction. All rats were given two further sessions of baseline training before being exposed to three extinction sessions. These extinction sessions were similar to baseline training, except that no food or tones were presented.

RESULTS AND DISCUSSION

The response rates for each rat, during the first three phases, are displayed in Figure 4. The final four sessions of each phase are used for analysis. In the baseline phases (Phases 1 and 3), more responses occurred during the component with an uncorrelated stimulus

than during the component with unsignaled reinforcement. During the last four sessions, response rates for all rats were stable and did not vary by more than three responses per minute for any rat. For all rats, response rates were lower in Phase 2 than they were in either of the baseline phases. For all rats, a greater response-rate decrease occurred in the component with unsignaled reinforcement than in the component with an uncorrelated stimulus. Response rates to the non-operative lever were not substantial for any rat in any phase.

Response rates during the last four sessions of Phase 2 calculated as a percentage of responding during the last four sessions of Phases 1 and 3 are displayed in Figure 5. In both cases, the reduction from baseline was much less in the component with an uncorrelated stimulus than in the component with unsignaled reinforcement.

Figure 6 displays the rate of responding during the two prefeeding sessions presented as a percentage of response rates from the two baseline sessions immediately preceding each prefeeding session. For all rats, responding was reduced more by prefeeding in the component with unsignaled reinforcement than in the component with an uncorrelated stimulus. Figure 6 also displays the rate of responding during the three extinction sessions as a percentage of response rates in the two sessions preceding extinction. For all rats, responding extinguished more slowly in the component that previously had an uncorrelated stimulus than in the component that previously had unsignaled reinforcement. As with Experiment 1, this effect was observed in extinction despite a greater stimulus change in the signaled component compared to the component with unsignaled reinforcement. The data on which Figure 6 is based are displayed in Appendix B.

These data suggest that a response-dependent stimulus, presented uncorrelated with reinforcer delivery, increases both response rate and resistance to change. This result is consistent with the notion that the uncorrelated stimulus serves to elevate responding through a quasi-reinforcement effect (e.g., Neuringer & Chung, 1967; Reed & Hall, 1989). The results from the resistance-to-change tests also are consistent with this suggestion—responding under the putatively

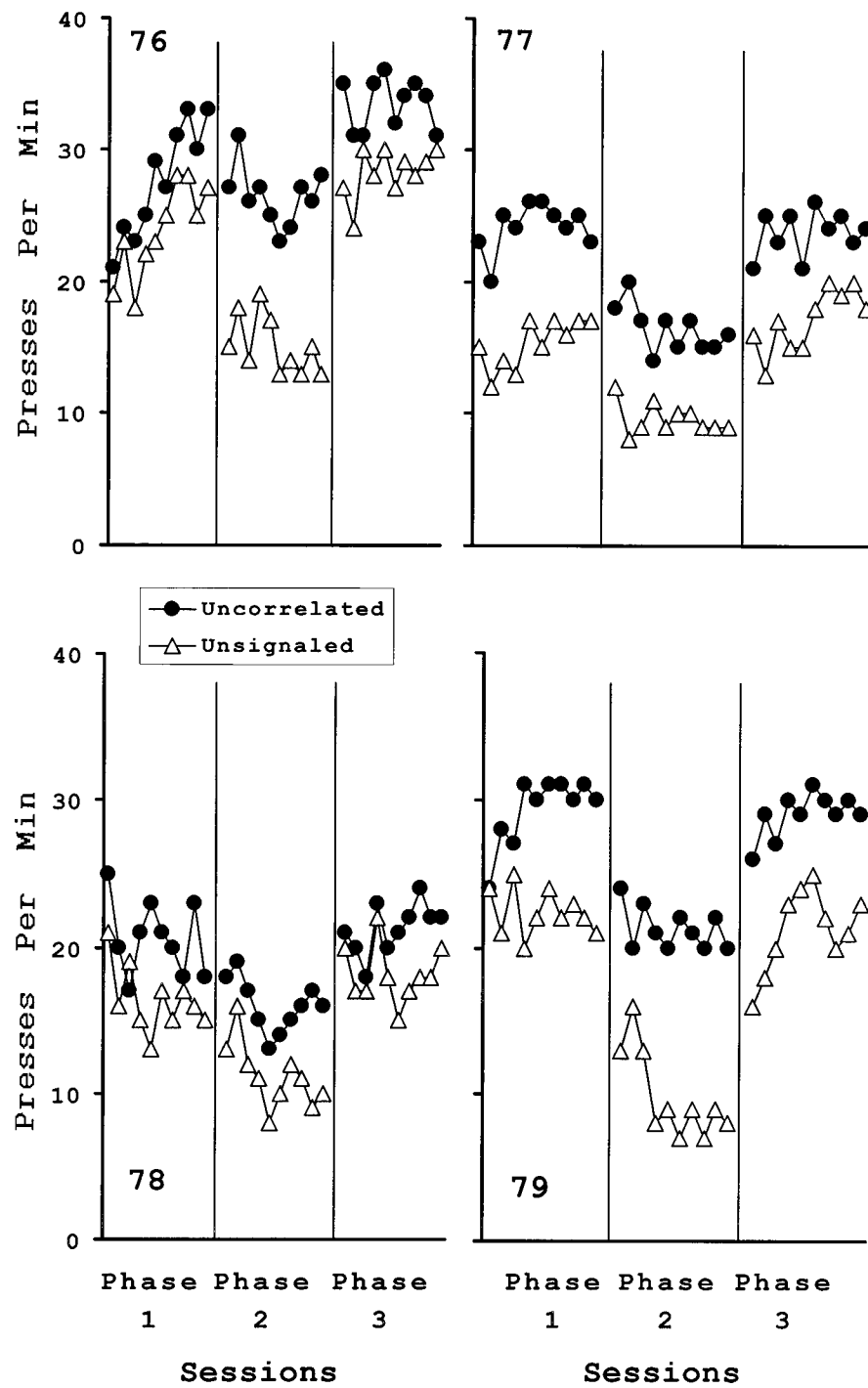


Fig. 4. Response rates for all rats in each component during all sessions of Phase 1 (baseline), Phase 2 (ICI food), and Phase 3 (baseline) in Experiment 2.

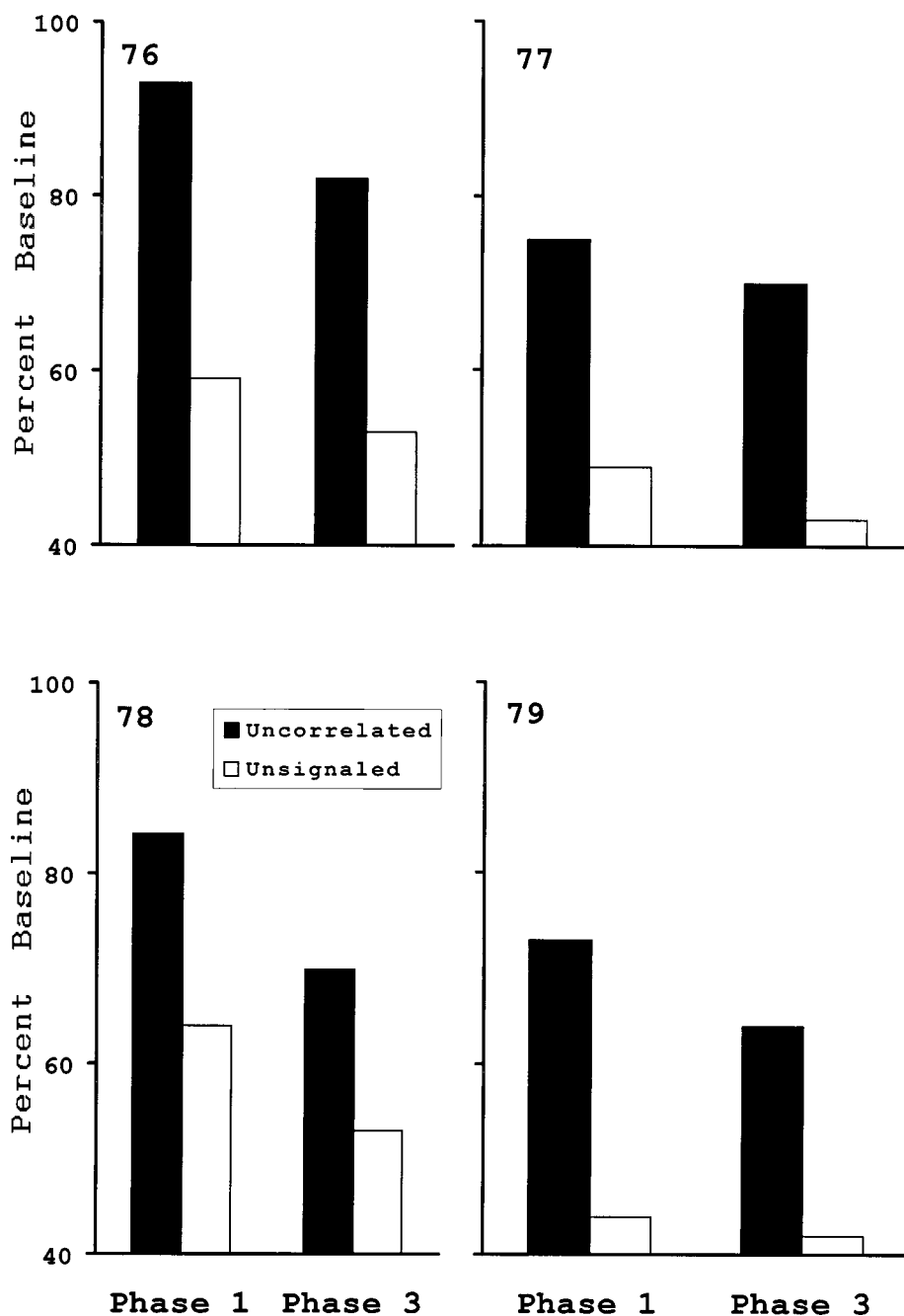


Fig. 5. Response rates for all rats in each component in Phase 2 (ICI food) expressed as a percentage of response rates from Phases 1 and 3 in Experiment 2.

richer schedule (i.e., with the uncorrelated stimulus) showing less disruption than responding maintained by the unsignaled RI 60-s schedule.

These results also demonstrate what has

been apparent from earlier studies of the effects of response-dependent but reinforcement-uncorrelated stimuli on behavior. That is, such stimuli are not neutral with respect to their effects on behavior. Rather, if such

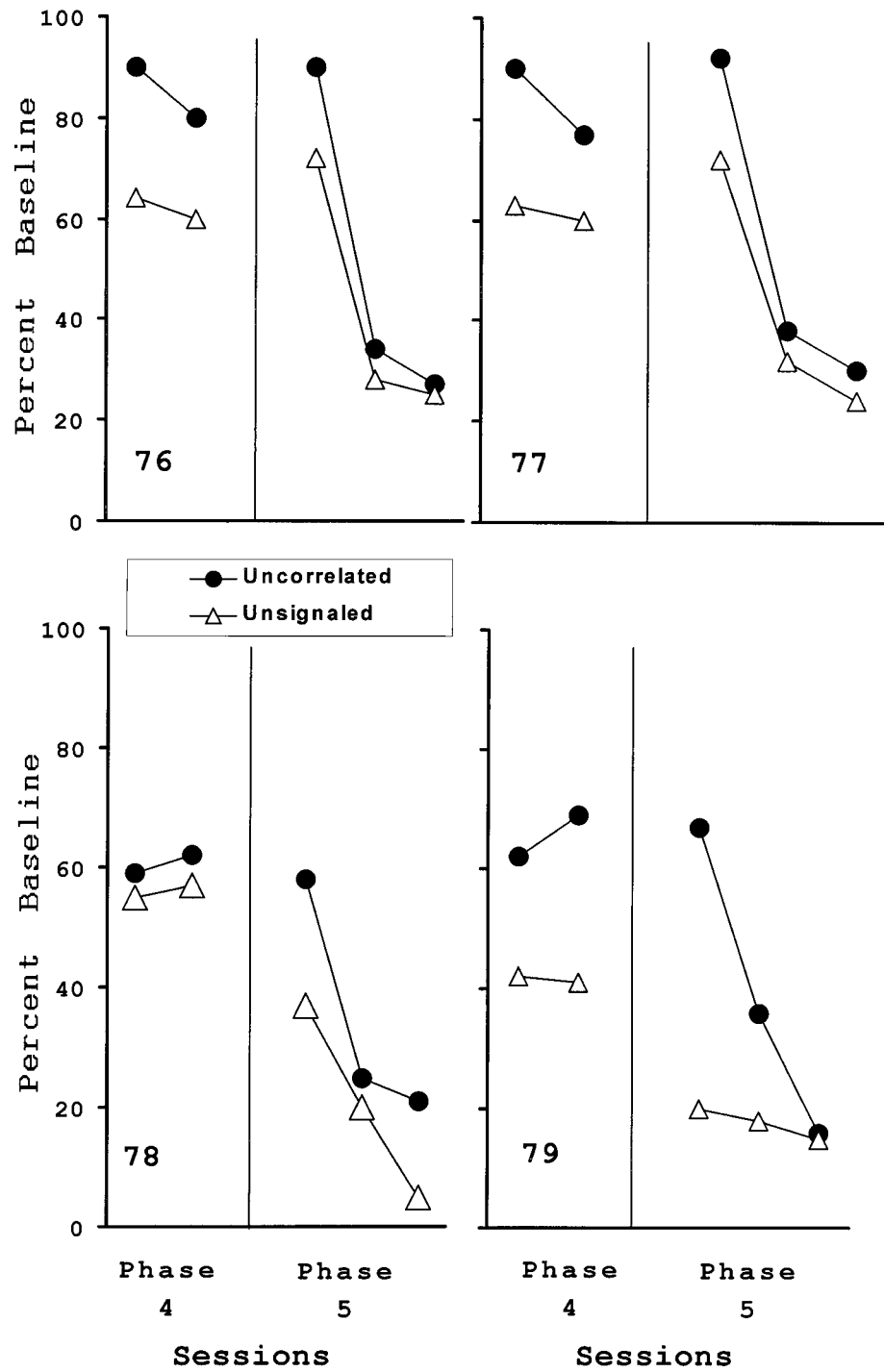


Fig. 6. Response rates expressed as a percentage of baseline for all rats in each component in Phase 4 (prefeeding) and Phase 5 (extinction) in Experiment 2.

uncorrelated stimuli acted as quasi-reinforcers, they would serve to elevate response rates relative to an RI condition in which the signal occurs along with reinforcement (and either reduce or elevate rates relative to a condition with no uncorrelated stimulus on a VR schedule depending on the value of the VR schedule employed; see Reed & Hall, 1989). The fact that these stimuli are not neutral limits their usefulness as a control for the effects of signaled reinforcement. The presentation of response-independent stimuli uncorrelated with reinforcement may control for the presence of a stimulus *per se* relative to a signaled reinforcement condition, but this control condition introduces other factors, such as quasi-reinforcement, that also affect behavior.

GENERAL DISCUSSION

The present study was conducted to explore the generality of the signaled-reinforcement effect (e.g., Pearce & Hall, 1978), and the response-strength results reported by Roberts et al. (1984). The present findings replicated the signaled- versus unsignaled-reinforcement phenomenon (Pearce & Hall, 1978); responding maintained by signaled reinforcement was lower than that maintained by unsignaled reinforcement on an RI 60-s schedule. This signal preceding reinforcer delivery also produced greater resistance to change, corroborating and extending the results reported by Roberts et al. These findings bear on a number of theoretical issues. First, they have implications for the conceptualization of the processes through which a signal for reinforcement operates. Second, they have implications for the generality of theories of response strength (e.g., behavioral momentum), in that they challenge any account based solely on reinforcer rate.

The signaled-reinforcement effect has been attributed to various factors, including overshadowing of the response-reinforcer association (Pearce & Hall, 1978), response efficiency (Roberts et al., 1984), and enhanced response learning (Reed, 1989). The resistance-to-change findings reported in the present study, and those reported previously (e.g., Roberts et al., 1984), make it unlikely that overshadowing can accommodate the signaled-reinforcement effect. According to the overshadowing interpretation, a weaker

response-reinforcer association results under RI-schedule training when a signal accompanies reinforcer delivery. It is unclear how an overshadowing view that predicts weaker learning could be used to interpret the greater resistance to change (indicative of stronger learning) that occurs after training with signaled reinforcement.

The present findings are consistent with a response-efficiency account of the signaled-reinforcement effect (Roberts et al., 1984). According to such a view, a signal accompanying the presentation of a reinforcer acts to facilitate the operating contingency of reinforcement, resulting in enhanced (or stronger) learning. If resistance-to-change measures index such learning, then the present results are consistent with such an interpretation of the signaled-reinforcement effect. These findings also are consistent with an interpretation based on enhanced response learning (Reed, 1989). If it is assumed that what is learned on an RI schedule is a pause-press pattern of responding (i.e., longer rather than shorter IRTs), then signal-induced potentiation of pausing would lead to lower rates of responding than if the signal had not promoted this response learning. In the disruption phase, removal of response patterns containing long IRTs would lead to a smaller decline in lever pressing than removal of units containing shorter IRTs (there being more opportunity for lever pressing in the latter case). Whichever of these views proves to be correct, it is clear that a signal promotes rather than retards learning or response strength.

The processes that promote signal-enhanced learning have been debated (cf. Reed, 1989; Roberts et al., 1984). One interpretation concerning how such a signal works, consistent with the present resistance-to-change findings, is based on conditioned reinforcement (e.g., see Williams, 1994a, 1994b, for reviews). As the presence of the signal is reliably correlated and contiguous with primary reinforcement, it serves as an additional source of reinforcement. This enhanced reinforcer presentation, relative to an unsignaled condition, serves to promote learning. As a result, better schedule-appropriate responding emerges. A conditioned-reinforcement account of the signaled-reinforcement effect also appears to be

supported by the present resistance-to-change findings. That is, when two components arrange equal rates of primary reinforcement, but one contains additional conditioned reinforcement, then greater resistance to change is predicted in the component with the additional conditioned reinforcement (see Bell, 1999). Although the present data are consistent with such a conditioned-reinforcement view, other findings (e.g., Reed, 1989) suggest that a reinforcement signal does not necessarily have to acquire secondary-reinforcing properties to enhance learning. Such findings indicate that the cue may serve to promote learning about the response without itself becoming associated with the reinforcer.

The results from Experiment 2 also suggest that a signal does not have to be contiguous with reinforcement to exert an influence on behavior. In fact, Reed and Hall (1989) have demonstrated that such cues can serve as quasi-reinforcers despite having conditioned inhibitory properties themselves. When this finding is coupled with the results from studies in which electric shocks have been found to serve as quasi-reinforcers (e.g., Byrd, 1969; Keenan & Leslie, 1981; Kelleher & Morse, 1968), it is apparent that the hedonic properties of the cue itself have little bearing on its function, but rather that its relation to the operative schedule is critical in determining its influence on behavior. Given these findings, it may be better to speak of the response-enhancing properties of such brief stimuli rather than of their conditioned-reinforcing properties. This terminology would allow both the signaled reinforcement effect (Experiment 1) and the quasi-reinforcement effect (Experiment 2) to be described in the same terms. Although nothing suggests that a conditioned reinforcer must be defined by its "hedonic" properties or by its contiguous relationship to primary reinforcement, it probably should be capable of supporting and not suppressing responding when presented on its own.

The above discussions suggest that a theory of response strength must take into account factors other than reinforcer rate. The present study, as well as others (Bell, 1999; Doughty & Lattal, 2001; Grace, Schwendimen, & Nevin, 1998; Lattal, 1989; Mellon & Shull, 1986; Nevin et al., 2001), have reported

differential resistance to change despite equal reinforcer rates. Doughty and Lattal reported that operant variation was more resistant to change than operant repetition. They integrated their findings with previous work by concluding that, at least when reinforcer rate is equated, a response pattern consisting of a greater number of members is stronger than a response pattern with fewer members. Such an interpretation of response strength may be applied to the present results by assuming that the presence of the signal engendered unrecorded responses other than the lever press. These other responses then gained some level of strength during training that, when summated with the lever press itself, made that response class relatively stronger than the lever press alone in the component with unsignaled reinforcement (cf. Baum, 2002).

It should be noted that the effects in the present experiments were produced after relatively few training sessions. Typically, many more sessions are required to produce stability. However, it should be noted that rate of responding during the baseline phases in the present study was reasonably stable. Responding during baseline did not vary by more than five responses per minute for any rat, nor did it show systematic trends in the data. However, irrespective of whether responding was stable, there were consistent effects across rats in both experiments. Moreover, the signaled-reinforcement effect might be observed most readily during the early stages of training. After extended training, and during stable (asymptotic) performance, there may be no scope for observing the effect (i.e., the effect may be relatively transient). Another point is that the signaled-reinforcement effect occurs in rats whether the signal is presented during a brief delay prior to reinforcement delivery (e.g., Pearce & Hall, 1978), or along with reinforcement as in this study. This fact suggests that the signaled-reinforcement effect should be considered as separate from the effects observed in signaled-delay-of-reinforcement studies, for which there is an extensive literature (see Lattal, 1984).

REFERENCES

- Baum, W. M. (2002). From molecular to molar: A paradigm shift in behavior analysis. *Journal of the Experimental Analysis of Behavior*, 78, 95–116.

- Bell, M. C. (1999). Pavlovian contingencies and resistance to change in a multiple schedule. *Journal of the Experimental Analysis of Behavior*, 72, 81–96.
- Byrd, L. D. (1969). Responding in the cat maintained under response-independent electric shock and response-produced electric shock. *Journal of the Experimental Analysis of Behavior*, 12, 1–10.
- Doughty, A. H., & Lattal, K. A. (2001). Resistance to change of operant variation and repetition. *Journal of the Experimental Analysis of Behavior*, 76, 195–215.
- Grace, R. C., Schwendimen, J. W., & Nevin, J. A. (1998). Effects of unsignaled delay of reinforcement on preference and resistance to change. *Journal of the Experimental Analysis of Behavior*, 69, 247–261.
- Keenan, M., & Leslie, J. C. (1981). Effects of fixed-time shocks and brief stimuli on food maintained behavior of rats. *Journal of the Experimental Analysis of Behavior*, 36, 353–361.
- Kelleher, R. T., & Morse, W. H. (1968). Schedules using noxious stimuli: III. Responding maintained with response-produced electric shocks. *Journal of the Experimental Analysis of Behavior*, 11, 819–838.
- Lattal, K. A. (1984). Signal functions in delayed reinforcement. *Journal of the Experimental Analysis of Behavior*, 42, 239–253.
- Lattal, K. A. (1989). Contingencies on response rate and resistance to change. *Learning and Motivation*, 20, 191–203.
- Mellon, R. C., & Shull, R. L. (1986). Resistance to change produced by access to fixed-delay versus variable-delay terminal links. *Journal of the Experimental Analysis of Behavior*, 46, 79–92.
- Neuringer, A. J., & Chung, S-H. (1967). Quasi-reinforcement: Control of responding by a percentage-reinforcement schedule. *Journal of the Experimental Analysis of Behavior*, 10, 45–54.
- Nevin, J. A., Grace, R. C., Holland, S., & McLean, A. P. (2001). Variable-ratio versus variable interval schedules: Response rate, resistance to change, and preference. *Journal of the Experimental Analysis of Behavior*, 76, 43–74.
- Pearce, J. M., & Hall, G. (1978). Overshadowing in the instrumental conditioning of a lever-press response by a more valid predictor of the reinforcer. *Journal of Experimental Psychology: Animal Behavior Processes*, 4, 356–367.
- Reed, P. (1989). Influence of interresponse time reinforcement on signaled reward effect. *Journal of Experimental Psychology: Animal Behavior Processes*, 15, 224–231.
- Reed, P., & Hall, G. (1989). The quasi-reinforcement effect: The influence of brief stimuli uncorrelated with reinforcement on variable ratio schedules. *Learning and Motivation*, 20, 242–261.
- Reed, P., Schachtman, T. R., & Hall, G. (1988). Overshadowing and potentiation of instrumental responding in rats as a function of the schedule of reinforcement. *Learning and Motivation*, 19, 13–30.
- Roberts, J. E., Tarpy, R. M., & Lea, S. E. G. (1984). Stimulus-response overshadowing: Effects of signaled reward on instrumental responding as measured by response rate and resistance to change. *Journal of Experimental Psychology: Animal Behavior Processes*, 10, 244–255.
- Schachtman, T. R., Reed, P., & Hall, G. (1987). Attenuation and enhancement of instrumental responding by signals for reinforcement on a random-interval schedule. *Journal of Experimental Psychology: Animal Behavior Processes*, 13, 271–279.
- St. Claire-Smith, R. (1979). The overshadowing of instrumental conditioning by a stimulus that predicts reinforcement better than a response. *Animal Learning and Behavior*, 7, 224–228.
- Tarpy, R. M., & Roberts, J. E. (1985). Effects of signaled reward in instrumental conditioning: Enhanced learning of DRL and DRH schedules of reinforcement. *Animal Learning and Behavior*, 13, 6–12.
- Williams, B. A. (1994a). Conditioned reinforcement: Experimental and theoretical issues. *Behavior Analyst*, 17, 261–285.
- Williams, B. A. (1994b). Conditioned reinforcement: Neglected or outmoded explanatory construct? *Psychonomic Bulletin and Review*, 1, 457–475.

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APPENDIX A

Responses per minute in baseline and resistance to change phases of Experiment 1.

Rat	Base-line	Base-line	Prefeeding session 1	Base-line	Base-line	Prefeeding session 2	Base-line	Base-line	Extinction session 1	Extinction session 2	Extinction session 3
72 S	16	15	9	13	16	9	17	19	12	7	4
U	20	23	13	21	24	11	24	25	10	6	2
73 S	11	11	8	10	11	9	12	10	8	5	2
U	20	19	8	19	21	8	20	22	7	3	1
74 S	21	19	9	18	20	8	21	20	8	4	1
U	27	25	11	25	25	10	26	27	5	3	1
75 S	20	19	17	18	19	15	20	19	12	10	2
U	27	24	15	24	26	14	25	27	9	4	3

Note. S indicates signaled component; U indicates unsignaled component.

APPENDIX B

Responses per minute in baseline and resistance to change phases of Experiment 2.

Rat	Base- line	Base- line	Prefeeding session 1	Base- line	Base- line	Prefeeding session 2	Base- line	Base- line	Extinc- tion session 1	Extinc- tion session 2	Extinc- tion session 3
76 UC	29	32	27	30	31	24	30	32	28	11	9
76 US	24	27	16	25	28	16	26	32	20	9	7
77 UC	24	22	12	25	25	13	26	26	11	7	2
77 US	19	17	7	19	17	8	17	16	9	5	1
78 UC	22	19	12	20	21	13	22	23	13	6	5
78 US	15	14	8	15	16	9	18	19	7	4	1
79 UC	25	26	16	26	27	18	27	25	17	9	4
79 US	22	21	9	22	22	9	24	23	5	4	3

Note. UC indicates uncorrelated component; US indicates unsignaled component.